

BIOLOGICAL CRITERIA  
Technical Guidance for Streams and Small Rivers

**CHAPTER 7: (continued)**

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Water quality standards constitute the numerical and narrative criteria that, when achieved, will presumably protect a given designated use (Ohio EPA 1992). Chemical-specific criteria serve as the "targets" for wasteload allocations conducted under the TMDL (Total Maximum Daily Load) process, which is used to determine water quality-based effluent limits for point source discharges and, theoretically, load allocations for nonpoint sources (in connection with best management practices). Whole effluent toxicity limits consist of acute and chronic endpoints (based on laboratory toxicity tests) and a dilution method similar to that used to calculate chemical-specific limits. The biological criteria are used to directly determine aquatic life use attainment status for the EWH, WWH, and MWH use designations as is stated under the definition of each in the Ohio WQS.

The biological criteria designed for Ohio's rivers and streams incorporate the ecoregional reference approach. Within each of the State's five ecoregions, criteria for three biological indices have been derived. The indices include two measures of fish community structure and one measure of the benthic macroinvertebrate community. The combined indices provide a quantitative measure that can be compared to regional reference indices to assess use attainment.

The two fish community measures include the Index of Biotic Integrity (IBI) and the modified Index of Well Being (IWB). Both indices incorporate structural attributes of the fish community, while the IBI additionally incorporates functional (trophic) characteristics. The two indices incorporate a range of fish community attributes much broader than only species richness and relative abundance. For macroinvertebrate community measurements, Ohio EPA uses the Invertebrate Community Index (ICI). The ICI is a modification of the IBI concept, but has been adapted for use with macroinvertebrates. Like the IBI, ICI values incorporate functional aspects of the community.

Derivation of the above indices requires extensive sampling to provide the quantitative data necessary for analysis. The IBI and IWB require sampling of approximately 500 meters of a river or stream by electroshocking to characterize the community of fish. Data recording is extensive, and includes fish species, number of individuals per species, and various observations of fish condition. The ICI requires that quantitative (Hester-Dendy) and qualitative macroinvertebrate samples be collected. Laboratory analysis of these samples includes taxon determination to genus or species, and quantification of the organisms collected.

The Exceptional Warmwater Habitat (EWH) is the most protective use assigned to warmwater streams in Ohio. Ohio's biological criteria for EWH applies uniformly statewide and is set at the 75th percentile index values of all reference sites combined. The Warmwater Habitat (WWH) is the most widely applied use designation assigned to warmwater streams in Ohio. The biological criteria for fish vary by ecoregion and site type and are set at the 25th percentile index values of the applicable reference sites in each ecoregion (Fig. 7-3a). A modified procedure was used in the extensively modified Huron Erie Lake Plain (HELP) ecoregion.

The Modified Warmwater Habitat (MWH), first adopted in 1990, is assigned to streams that have had *extensive* and irretrievable physical habitat modifications. The MWH use does not meet the Clean Water Act goals and therefore requires a Use Attainability Analysis. There are three sub-

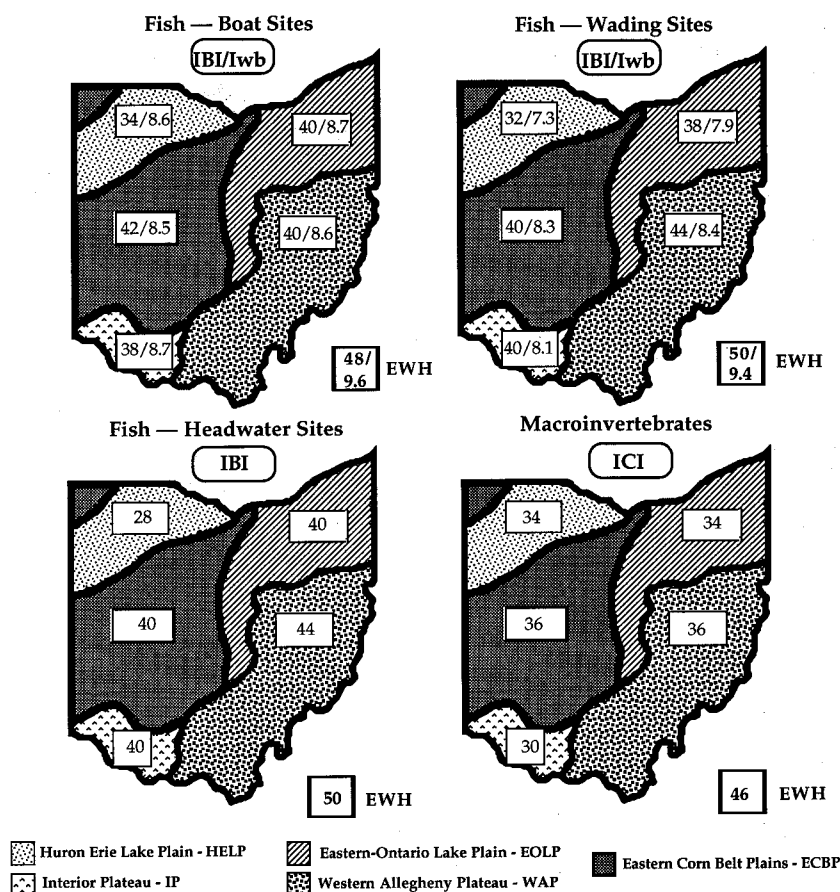
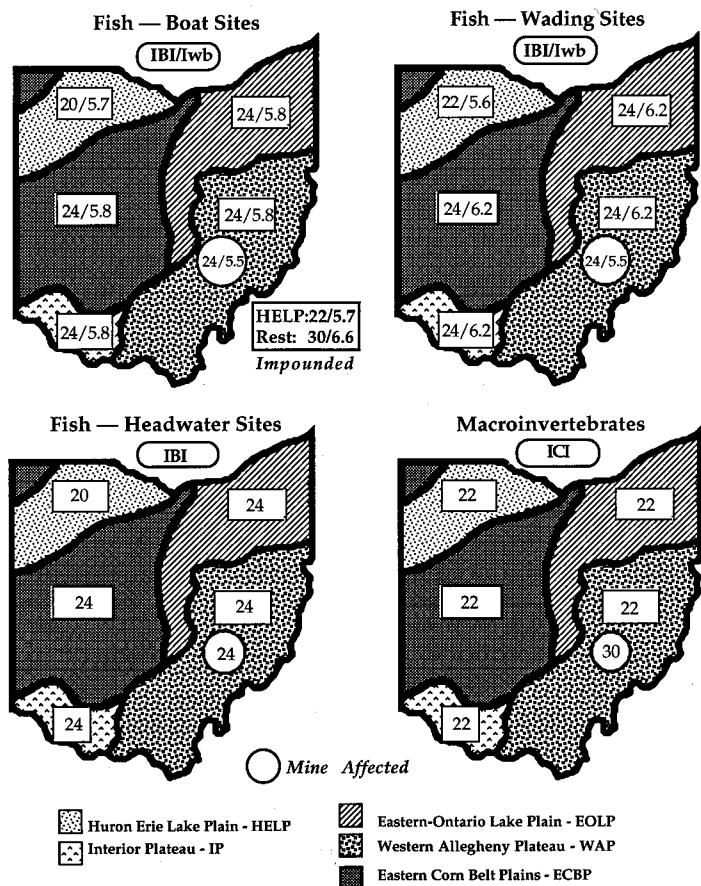


Figure 7-3a.— Biological criteria in the Ohio WQS for the Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) use designations arranged by biological index, site type for fish, and ecoregion. Index values in the boxes on each map are the WWH biocriteria that vary by ecoregion as follows: IBI/MIwb for Boat Sites (upper left), IBI/MIwb for Wading Sites (upper right), IBI for Headwaters Sites (lower left), and the ICI (lower right). The EWH criteria for each index and site type are located in the boxes just outside each map (Ohio EPA, 1992).

categories: MWH-A, non-acidic mine runoff affected habitats; MWH-C, channel modified habitats; and MWH-I, extensively impounded habitats. Biological criteria were derived from a separate set of modified reference sites. The biocriteria were set separately for each of three categories of habitat impact (Fig. 7-3b). The MWH-C and MWH-I subcategory biocriteria were also derived separately for the HELP ecoregion. The MWH-A applies only within the Western Allegheny Plateau (WAP) ecoregion.

## Costs for State Programs Developing Bioassessments and Biocriteria

Biocriteria programs begin with the development of a bioassessment framework. Expertise in ecological principles and resource investment by the agency is required to develop this framework and to implement biocriteria. State agencies will vary in their investment of resources and effort in this process.



**Figure 7-3b.—Biological criteria in the Ohio WQS for the Modified Warmwater Habitat (MWH) use designation arranged by biological index, site type for fish, modification type, and ecoregion. Index values in the boxes on each map are the MWH biocriteria for the channelized modification type that vary by ecoregion as follows: IBI/MIwb for Boat Sites (upper left), IBI/MIwb for Wading Sites (upper right), IBI for Headwaters Sites (lower left), and the ICI (lower right). The MWH criteria for the Impounded modification type is located in the box just outside the Boat Sites map. The biocriteria for the mine-affected modification type is represented by the circled value located in the WAP ecoregion on each map (Ohio EPA, 1992).**

Several states that have initiated biocriteria programs were polled to obtain estimates of their cost and resource needs. These cost estimates represent a range of program elements including assemblage selection (benthic macroinvertebrates and fish) and geographical coverage (statewide or targeted regions of the state). The following paragraphs briefly characterize each of the state programs included in the poll before extrapolating cost estimates in terms of funding and personnel.

■ **Delaware.** The nontidal streams in Delaware are mostly low-gradient coastal streams that drain agricultural lands. Delaware Department of Natural Resources and Environmental Control (DNREC) developed a modification of the EPA's rapid bioassessment protocols to sample benthic macroinvertebrate from multihabitats in these streams. Technical issues addressed in developing their bioassessment included standardized methods, level of subsampling, taxonomic level (family or genus), and the se-

lection of appropriate metrics. Samples are collected during a specified index period that extends from late summer through the fall season. Biosurveys done by department biologists include survey planning, collection, processing, and data analysis. Consultants are used to assist in processing benthic samples for large projects.

■ **Florida.** Florida Department of Environmental Protection (DEP; formerly the Department of Environmental Regulation) used a combination of in-house biologists, scientists from the EPA's Environmental Research Laboratory in Corvallis, and consultants to develop a statewide stream bioassessment program based on thorough site regionalization and methods development projects. Florida DEP samples benthic macroinvertebrates from multiple stream habitats using a modified RBP method, and assesses biological condition using a suite of metrics. The sampling sites are classified into aggregated subcoregions for determination of appropriate reference conditions. Currently, the portions of Florida that are not adequately delineated are south Florida, south of Lake Okeechobee, and northeastern Florida around Jacksonville. Two index periods are used to assess biological condition—August through September, and January through February. Florida DEP biologists collect and process all samples. Outside consultants are used to analyze the data and develop taxonomic keys.

■ **Idaho.** Both fish and benthic macroinvertebrates are surveyed by Idaho Department of Environmental Quality (DEQ) as part of Idaho's monitoring program. Their biological program is a relatively intense part of a multiyear monitoring effort to assess nonpoint source impacts. Idaho DEQ is now evaluating their current program and refining their biological methods. Consultants are used to assist in this process. The field sampling and sample analysis are conducted by Idaho DEQ regional staff.

■ **Maine.** Maine Department of Environmental Protection (DEP) uses rock-filled baskets as introduced substrate for macroinvertebrate colonization. The statewide program uses aquatic life use designations to establish reference conditions. Numeric biocriteria have recently been incorporated in Maine's rules. Analysis is done using a tiered multivariate procedure that incorporates information from up to 35 metrics. Maine's index period is in the summer. Virtually all of its bioassessment is accomplished by Maine DEP biologists.

■ **Nebraska.** Both fish and benthic macroinvertebrates are sampled in Nebraska by the Department of Environmental Quality (DEQ). A multimetric approach is used for both assemblages, based on the IBI for fish and EPA's RBPs for benthos. Reference conditions have been determined for each ecoregion in Nebraska and a summer index period is used to sample streams. Nebraska's biological monitoring program was developed and is maintained by DEQ biologists.

■ **North Carolina.** The Department of Environment, Health, and Natural Resources (DEHNR) of North Carolina has had an effective bioassessment program in place for several years. A standardized macroinvertebrate sampling procedure is used to sample multiple habitats in North Carolina streams; metrics are used to assess biological condition, and judgment criteria are based on the ecoregion level of site classification. The design and

development of the program as well as all aspects of monitoring are conducted by DEHNR biologists.

■ **Ohio.** Ohio EPA has developed both a fish and benthic macroinvertebrate protocol for conducting bioassessments in Ohio's streams and rivers. A multimetric approach is used in both protocols that focuses on a summer index period. Site classification is by ecoregion with a given percentage of the sites monitored on an annual basis. Numeric biocriteria are included in Ohio's water resource program. They were developed in a hierarchical manner by aquatic life use and ecoregion. Ohio EPA staff designed and developed the bioassessment program, and conducts the annual sampling with in-house staff and summer interns.

■ **Oklahoma.** The Oklahoma Conservation Commission (OCC) has developed a biological assessment program that includes benthic macroinvertebrate, fish, and periphyton sampling to evaluate nonpoint source effects. However, the benthic program is central and reflects the cost of developing the program which is statewide and loosely based on ecoregions. The index period is summer, and monitoring during other seasons is dependent on the case study. Technical consultants were used to help establish the reference condition.

■ **Oregon.** Oregon Department of Environmental Quality (DEQ) has developed a modified RBP approach for surveying benthic macroinvertebrates and fish in streams in the Coastal Range. The other five ecoregions have not been extensively sampled to date. Multiple metrics are calculated and used to assess biological condition. A single fall index period (September, October, November) is emphasized. However, monitoring is done in other seasons to evaluate specific impacts, for example, forest insecticide application. The majority of the biosurvey and assessment is done by DEQ biologists.

Turning now to costs: it is apparent from the states polled that a minimum of two full-time equivalent staff are needed for the development of an effective biological assessment program. The states of Ohio, Maine, North Carolina, and Florida have invested the equivalent of 12 staff (or more) to develop their programs (Table 7-4). However, Ohio EPA points out that only 19 percent of their surface water monitoring program is devoted to biological monitoring (Yoder and Rankin, 1994). When considered on the basis of agencywide water programs, Ohio EPA allocates 6 percent to biological monitoring.

Cost investment will vary depending on the geographical coverage (number of stream miles), the extent of coverage, biological approach and targeted assemblages, and the extent of shared resources (e.g., other state and federal agency assistance, and shared reference conditions). Nebraska and Ohio have developed their program statewide for fish and benthos, whereas other states polled emphasized only benthos and some have not covered the whole state (Table 7-5). Although Delaware and Florida have only partial coverage to date, their programs are relatively complete and are pertinent for the majority of their state streams. A few of the states have used contractor support, which ranged from \$10,000 to \$350,000.

Though self-reported, the costs reviewed here are typical costs incurred by state bioassessment programs.

## Value of Biocriteria in Assessing Impairment

Water resource agencies currently use several tools to assess impairment and monitor changes. However, these tools can be separated into three distinct categories: chemical analysis of water samples, toxicity testing of selected species, and biosurveys. These tools, though not interchangeable in all cases, are most effective when used in conjunction with each other. Chemical and toxicity criteria, however, are only useful for assessing adverse impacts from chemical discharges. Biosurveys and biocriteria are more appropriate than other tools for measuring cumulative or synergistic impacts, the status of the resources, and impairment from stressors other than chemical contamination, such as habitat degradation.

**Table 7-4.— The investment of state water resource agency staff needed to develop bioassessment programs as a framework for biocriteria.**

FULL-TIME EQUIVALENT (FTE) STAFF						
STATES	STANDARDIZE METHODS	SITE CLASSIFICATION	FIELD SURVEY	REFERENCE CONDITION	METRICS AND INDICES	DEVELOPMENT TOTAL
Benthos and Fish [Statewide]						
Nebraska	0.04	0.73	0.88	0.28	0.49	2.4
Ohio	2.0	1.0	2.7	2.5	3.0	11.2
Benthos [Statewide]						
Maine	1.0	8.0	1.5	—	3.0	13.5
N. Carolina	8.0	1.0	4.0	2.0	1.0	16.0
Oklahoma	0.05	0.5	0.25	0.75	0.25	1.8
Benthos [Partial Coverage]						
Delaware	0.4	0.1	0.3	0.6	0.6	2.0
Florida	2.6	2.0	5.7	1.0	1.0	12.3
Oregon	0.25	0.25	1.0	1.0	0.5	3.0

**Table 7-5.— Costs associated with retaining consultants to develop bioassessment programs as a framework for biocriteria. Dash indicates work done by state employees or information not available; FTE costs for contractors and state employees are not equivalent.**

FULL-TIME EQUIVALENT (FTE) STAFF						
STATES	STANDARDIZE METHODS	SITE CLASSIFICATION	FIELD SURVEY	REFERENCE CONDITION	METRICS AND INDICES	DEVELOPMENT TOTAL
Benthos and Fish [Statewide]						
Nebraska	—	—	—	—	—	—
Ohio	—	—	—	—	—	—
Benthos [Statewide]						
Maine	—	8	36	—	13	57
N. Carolina	—	—	—	—	—	—
Oklahoma	—	—	—	25	—	25
Benthos [Partial Coverage]						
Delaware	55	5	—	—	40	100
Florida	100	210	—	75	75	350
Oregon	—	—	10	—	—	10

Several comparison studies were conducted and documented in the Technical Support Document for Water Quality-based Toxics Control (U.S. Environ. Prot. Agency, 1991). These studies used biosurvey results to calibrate the judgment of impairment using toxicity testing.

The Agency conducted studies at eight freshwater sites in which ambient toxicity was compared to the biological impact on the receiving water. These site studies were a part of the Complex Effluent Toxicity Testing Program (CETTP). Testing was performed on-site concurrent with the field surveys. Sites exhibiting biological impacts were included from Oklahoma, Alabama, Maryland, West Virginia, Ohio, and Connecticut. Organisms were exposed to samples of water from various stations and tested for toxicity. Biological surveys (quantitative field sampling of fish, invertebrate, zooplankton, and periphyton communities in the receiving water areas upstream and downstream of the discharge points) were made at these stations at the same time the toxicity was tested to see how well the measured toxicity correlated to the health of the community. These studies have been reviewed and published in an EPA publication series (Mount et al. 1984; 1985; 1986; 1986a; 1986b; Mount and Norberg-King 1985; 1986; Norberg-King and Mount 1986).

A robust canonical correlation analysis was performed to determine whether or not statistically significant relationships existed between the ambient toxicity tests and in-stream biological response variables and to identify which variables play an important role in that relationship (Dickson et al. 1992). Influential variables were then used to classify stations as either impacted or not. *Ceriodaphnia dubia* productivity and/or *Pimephales promelas* weight were used as the basis for predicting impact (U.S. Environ. Prot. Agency, 1991). Fish richness was used to classify streams as impact observed or impact not observed.

In this set of studies, agreement was obtained between the prediction of in-stream toxicity using ambient toxicity testing and the observed biological impairment from the biosurvey results (Fig. 7-4). However, at 10 percent of the sampling stations, agreement was not reached. EPA (1991) has said that this small difference in results would not significantly affect the diagnosis of impairment.

Another study conducted by the North Carolina Division of Environmental Management indicated the high accuracy of predicting receiving water impacts from whole effluent toxicity tests. Forty-three comparisons were made between freshwater flowing streams using the *Ceriodaphnia du-*

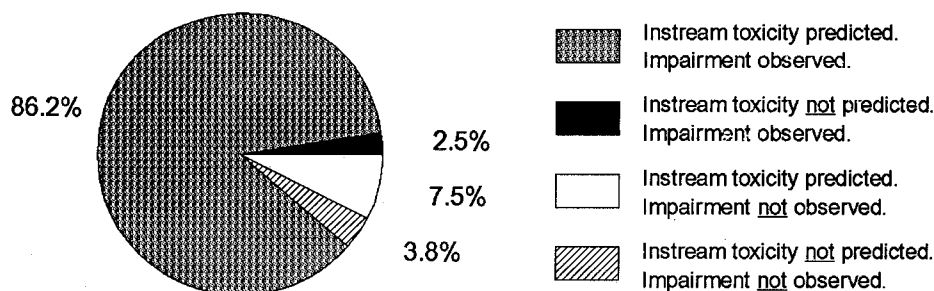


Figure 7-4.—Comparison of ambient toxicity and fish richness surveys at eight sites in various parts of the United States (taken from U.S. EPA, 1991).

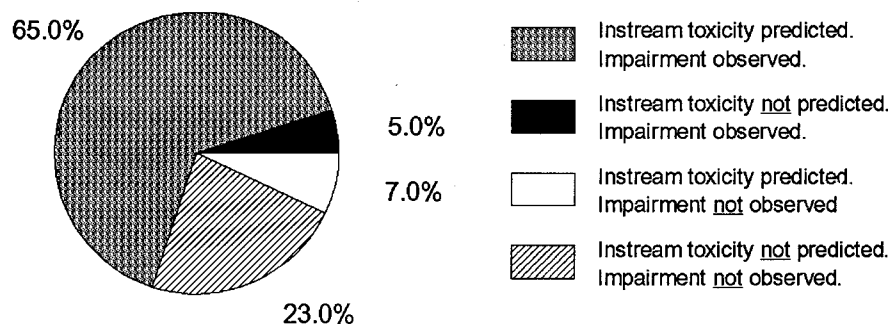


Figure 7-5.—Comparison of effluent toxicity of receiving water impact using *Ceriodaphnia dubia* chronic toxicity tests and freshwater receiving stream benthic invertebrates at 43 point source discharging sites in North Carolina (taken from U.S. EPA, 1991).

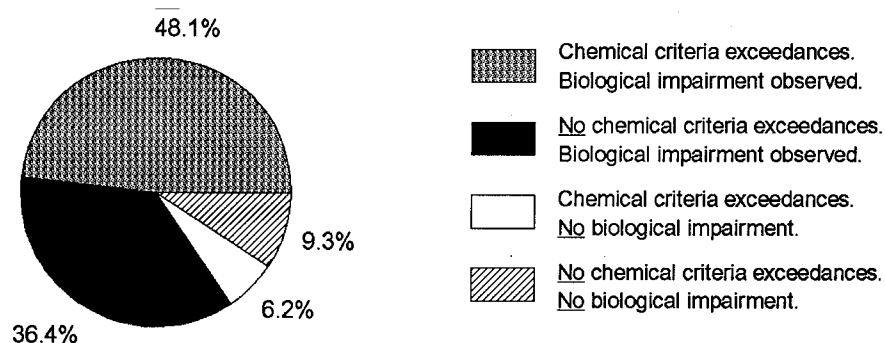


Figure 7-6.—Comparison of chemical criteria exceedances and biosurvey results at 645 stream segments in Ohio.

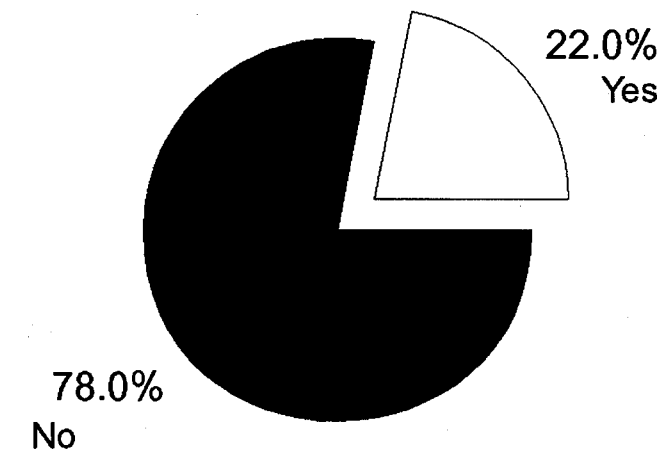
*bia* chronic test and a qualitative macroinvertebrate sampling. The result was an overall 88 percent accuracy of prediction (Fig. 7-5). However, in 12 percent of the cases, agreement was not reached. Both of these studies indicate that some risk of error exists if impairment is predicted using toxicity tests alone.

Chemical analyses are less accurate in predicting biological impairment. In a study conducted by Ohio EPA, the prediction of impairment from chemical analyses agreed with the biological survey results in only 47 percent of the cases (Fig. 7-6). Chemical analyses were unable to detect the impairment measured by biocriteria at 50 percent of the sites. Ohio EPA (1990) stated that the absence of detected chemical criteria exceedances when biological criteria impairment was indicated may result from several possibilities: (1) chemical parameters other than those sampled have been exceeded, (2) impairments of a nontoxic nature exist, (3) impairments stemming from physical impacts (e.g., habitat modification, flow alteration) exist, and/or (4) impairments related to biological interactions (e.g., exotics, disease) exist. None of these scenarios would be detected or fully understood using chemical criteria assessments alone.

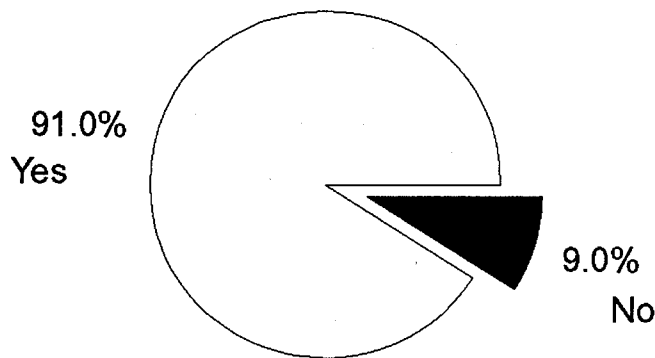
The Delaware Department of Natural Resources and Environmental Control assessed the attainment of their aquatic life use class for nontidal streams in 1994 using both their dissolved oxygen criteria and a biological endpoint. Results indicated that the use of the dissolved oxygen criteria

was inadequate to detect impairment to the aquatic life. Documentation of exceedances to the dissolved oxygen criteria suggested that only 9 percent of Delaware's nontidal streams failed to meet attainment (Fig. 7-7). Whereas the habitat and biological assessment approach indicated that 78 percent of the nontidal streams were not attaining their designated use.

These experiences support the observation that biological criteria are an excellent assessment tool and one that covers environmental variables not necessarily addressed by other chemical, physical, or effluent toxicity studies. While not yet advocated as a method for setting regulatory NPDES permit limits, the biocriteria process is clearly an essential means of environmental assessment and has in fact been used to review these permits and other management efforts in several states including Ohio, Maine, and North Carolina.



Fixed Stations - Dissolved Oxygen  
(No statistical confidence)



Probabilistic - Habitat/Biology  
(95% Confidence Interval +/- 5-6%)

Figure 7-7.—Assessment of nontidal stream aquatic life use attainment in Delaware.  
(taken from the state's 305[b] report, 1994).

## Suggested Readings

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